An Analysis of Transport, Dispersion, and Deposition from Two Above-Ground Nuclear Tests in China

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Background. There has been recent international interest on where nuclear fallout occurred from above ground test events conducted at the Chinese Lop Nor test site. This study pertains to detonations presumed to occur during the morning hours of June 17, 1967 and June 27, 1973. A map showing the location of the test site and towns of interest in Kazakhstan (Makanchi, Urdzhar, and Taskesken) are shown in Figure 1.

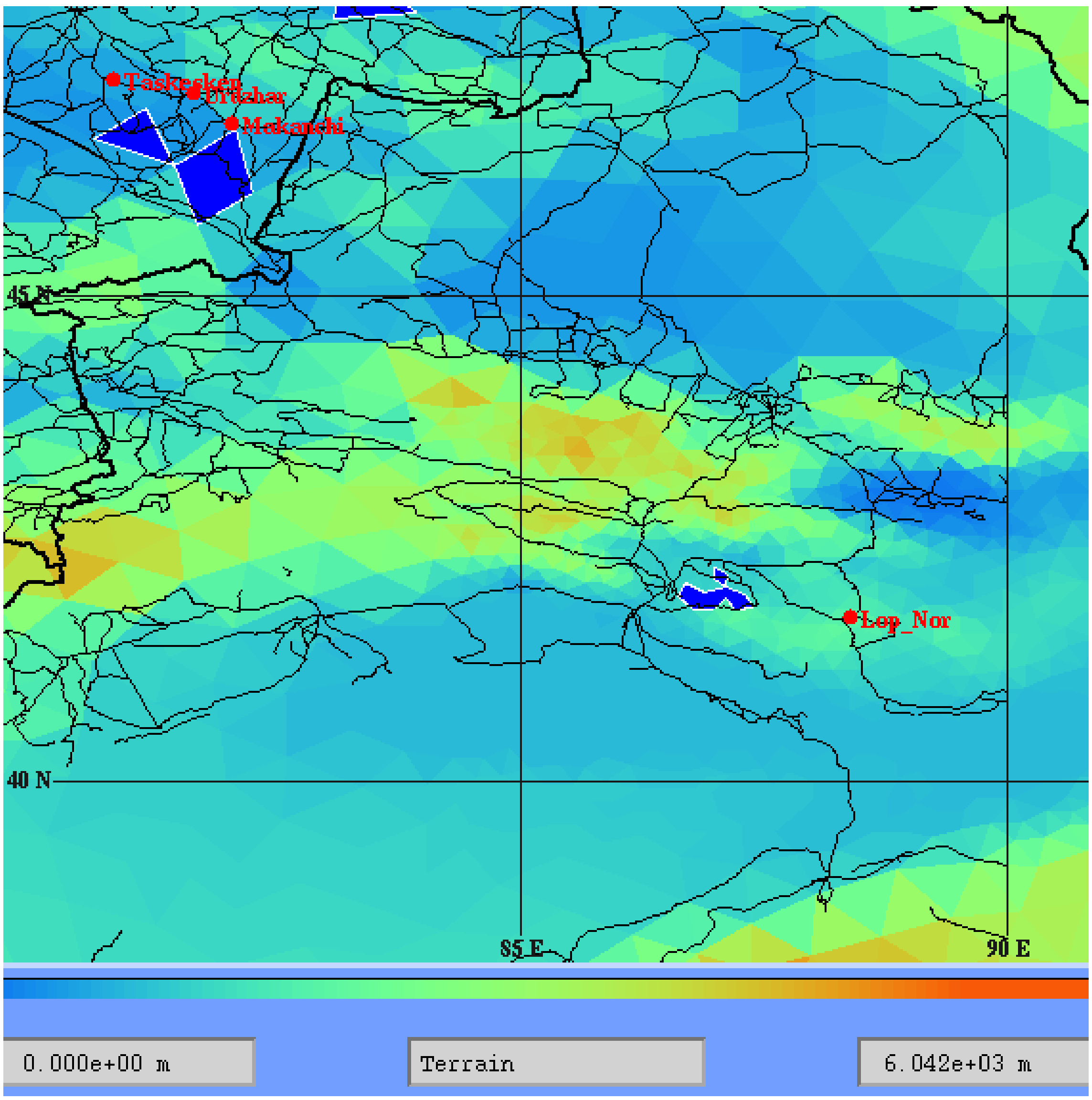

Figure 1 Map of the Lop Nor test site and Neighboring Kazakhstan. The background is a color gradient of terrain height, with scale indicated at the bottom. Mountain ranges are in orange and red. Heights range from 0 to 6042 meters**.** The small, dark blue regions are lakes represented by a triangular mesh at variable resolution.

Objective. The purpose of this study is to determine whether it is likely that significant fallout from the two aboveground nuclear weapons tests fell near the cities of Makanchi, Urdzhar, and Taskesken in Kazakhstan. To accomplish this it was necessary to reconstruct the regional meteorological conditions (winds, temperatures, and humidity), then perform nuclear weapon source term, transport, dispersion, and deposition calculations based on the best available information.

Procedures.

Meteorological - The Meteorological data used for the reconstruction are prepared for use in the HPAC model in several steps. The underlying data used are taken from the National Center for Atmospheric Research (NCAR)/National Center for Environmental Prediction (NCEP) Reanalysis Project. This combined NCAR/NCEP effort was an extensive undertaking aimed at collecting, quality control checking, and performing gridded model analyses of all obtainable meteorological data from present dating back to the 1940s. Once the data were assembled and quality control checked, they were input to the NCEP global meteorological analysis model that was run to create gridded data fields for the entire digitized meteorological history. The resulting data set, spanning about 50 years, is an excellent, consistent set of meteorological data that had never existed until the project's first phase completion, in 1997 (Kalnay, 1996).

The NCAR/NCEP data were formatted for use as boundary and initial conditions for the Colorado State University's Regional Atmospheric Modeling System (RAMS) (Tripoli and Cotton, 1982). The data were available at 6-hourly intervals. For this project RAMS was configured to run with a 60km-resolution grid covering a 4300x3700km area. The vertical grid contained 40 layers reaching up to a 30km altitude. The RAMS model was run out to 72 hours for both periods, 17-20 June 1967 and 27-30 June 1970. The resulting output (at hourly intervals) was formatted for input into HPAC for transport and diffusion calculations.

Hazard Prediction – The HPAC v3.1 system was used for source term generation, transport/diffusion, and radiation effects calculations (Bradley, 1997). The source term was created using the HPAC NWPN module, which is based on the legacy code for nuclear fallout, called NewFall (McGahan, 1996). Sample output from NewFall is provided in Figures 2 and 3, which demonstrate the vertical distribution of particle sizes and relative radioactivity levels. NewFall uses meteorological conditions (temperature, pressure, and humidity as a function of height) near the release to determine the extent of rise of the initial cloud.

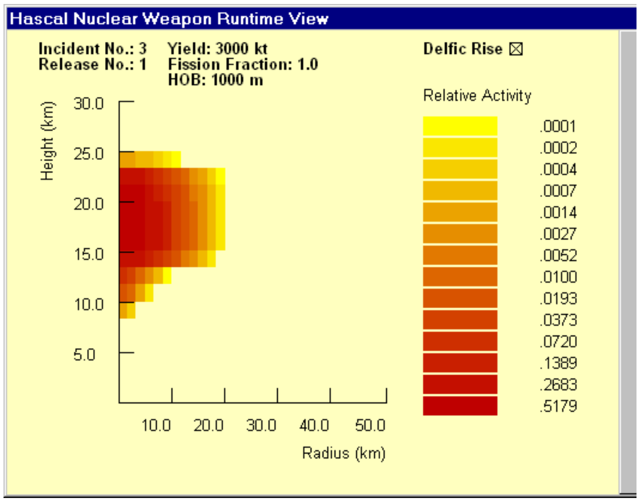

Figure 2 Relative radioactivity as a function of height of the initial cloud as determined by NewFall.

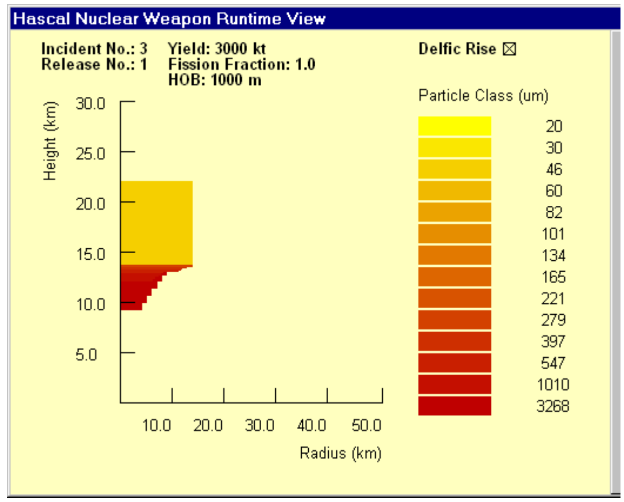

Figure 3 Particle size distribution of the initial cloud as determined by NewFall.

Since the height of burst (HOB) is unknown about the two tests, two altitudes that probably covered the possible range of heights were simulated and the results are presented below for comparison. The two HOBs used were 100 and 1000 meters, resulting in four different HPAC calculations, two for each weapon test. Since the time of detonation can only be narrowed to sometime between 0700 and 1200 local time (phone conversion with Col Glen Reeves, AFRRI, 6 Apr 99) a release time of 0900 (0300 UTC) was arbitrarily used for all four scenarios.

Once the source term is generated by NewFall, HPAC passes the resulting distribution of radioactive material to the Second-order Closure Integrated PUFF (SCIPUFF) model to perform the transport and diffusion of the material to determine the downwind hazard (Sykes, 1997). A discussion of the results for each series of calculations is provided below.

17 June 1967, 0300 UTC: The HPAC plume and resulting surface dosage calculation are shown in Figure 4 for the assumed 3MT detonation at 100m and 1000m HOBs. Figure 4 shows that the 100m HOB deposits radioactive material on the surface considerably farther downrange than the 1000m burst does. This is due to the fact that the lower burst altitudes can pick up a great deal more particles from the underlying ground and loft them much higher into the atmosphere. Both the 100m and 1000m bursts loft a considerable amount of material into the atmosphere that remains suspended for many days and is transported much farther than the plots shown indicate. The surface deposition in the domain shown in Figure 4 is largely completed in the 48-hour transport time used in the figure.

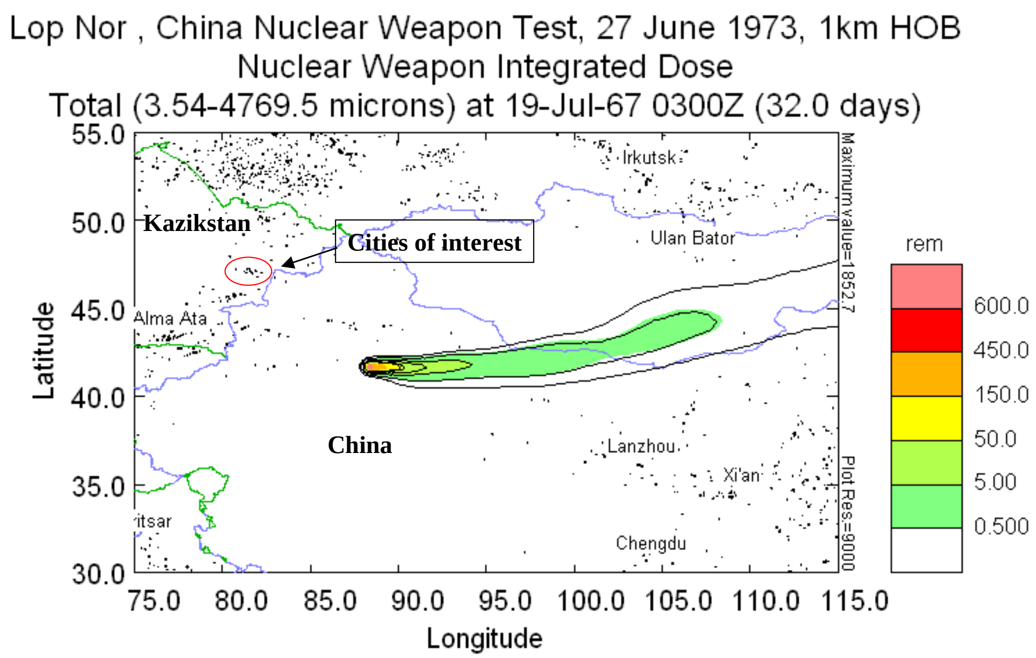

Figure 4. HPAC calculation showing a 32-day integrated radiation dose due to surface deposition of materials after a 48-hour transport. The 100m HOB calculation is shown as the overlay in black and the 1km HOB calculation is displayed in color with the contour scale shown on the right.

Since Newfall predicted a cloud rise with particles that reached about 20 km altitude, into the stratosphere by several kilometers, a large portion of the cloud will remain suspended for downwind transport. In addition, the cloud probably experienced considerable wind shear. A vertical cross section of the RAMS output (Figure 5) shows predictions of winds to be primarily out of the west below 18 km, with easterly winds above. This implies the heavier particles of the cloud will drift to the east while the smaller, lighter particles, lofted as high as 20km, may travel to the west for some time.

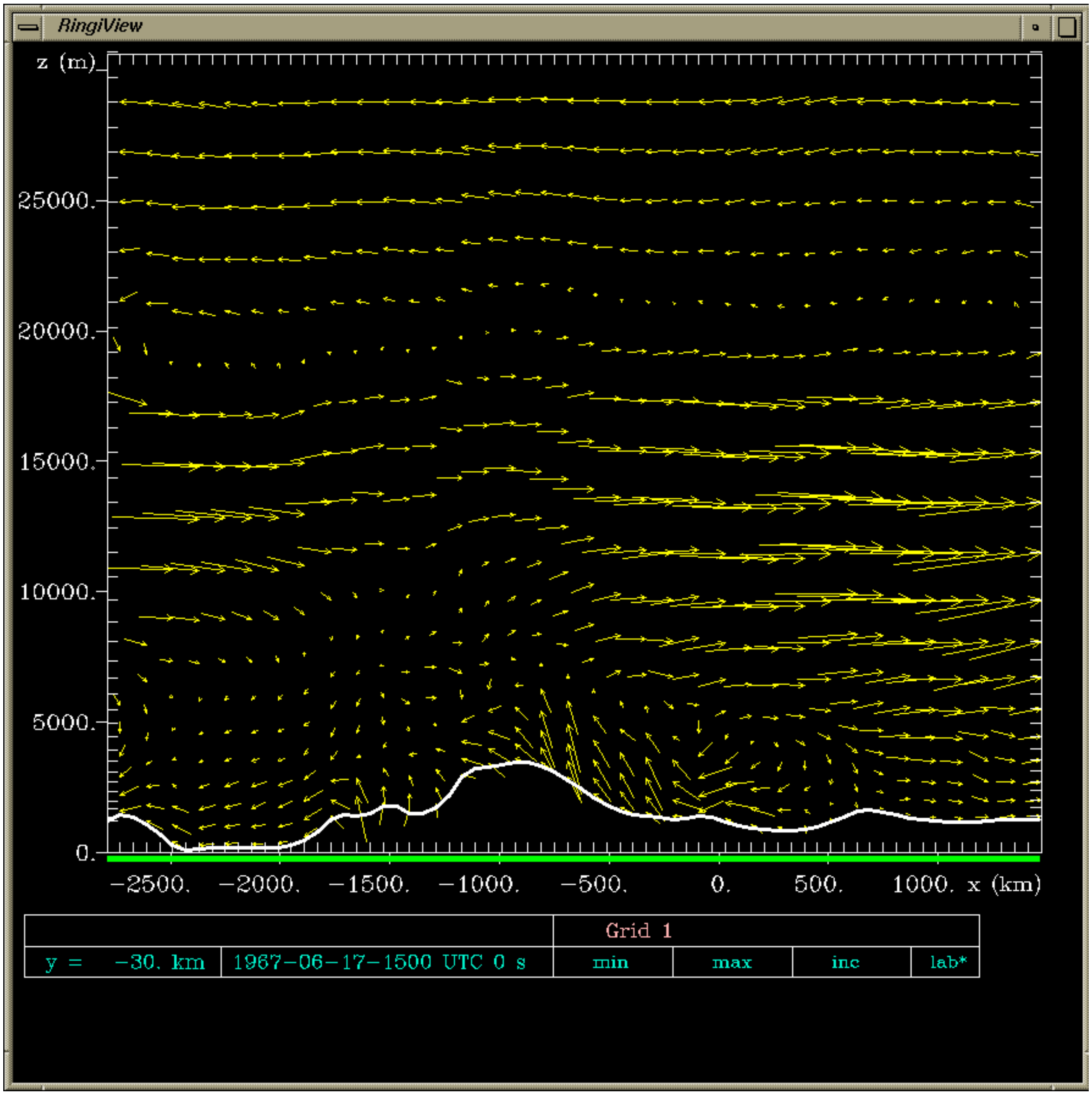

Figure 5 W-E vertical cross section showing wind layers at 41.4N latitude, 1500 UTC on June 17, 1967, the time corresponding to the top image of Figure 6. Left is west and east is on the right. Lop Nor is near a value of about -100 on the x-axis scale and somewhat north of the cross section shown.

As shown in Figure 6, some of the material does appear to get pushed into the easterly wind regime but not high enough to reach the stronger winds a few kilometers higher. Thus the anvil top only disperses gradually to the west at the higher altitudes. Though Figure 6 shows the only 100m HOB case, the 1km HOB case does not differ substantially in terms of the westward propagation of materials. A vast majority of the material is

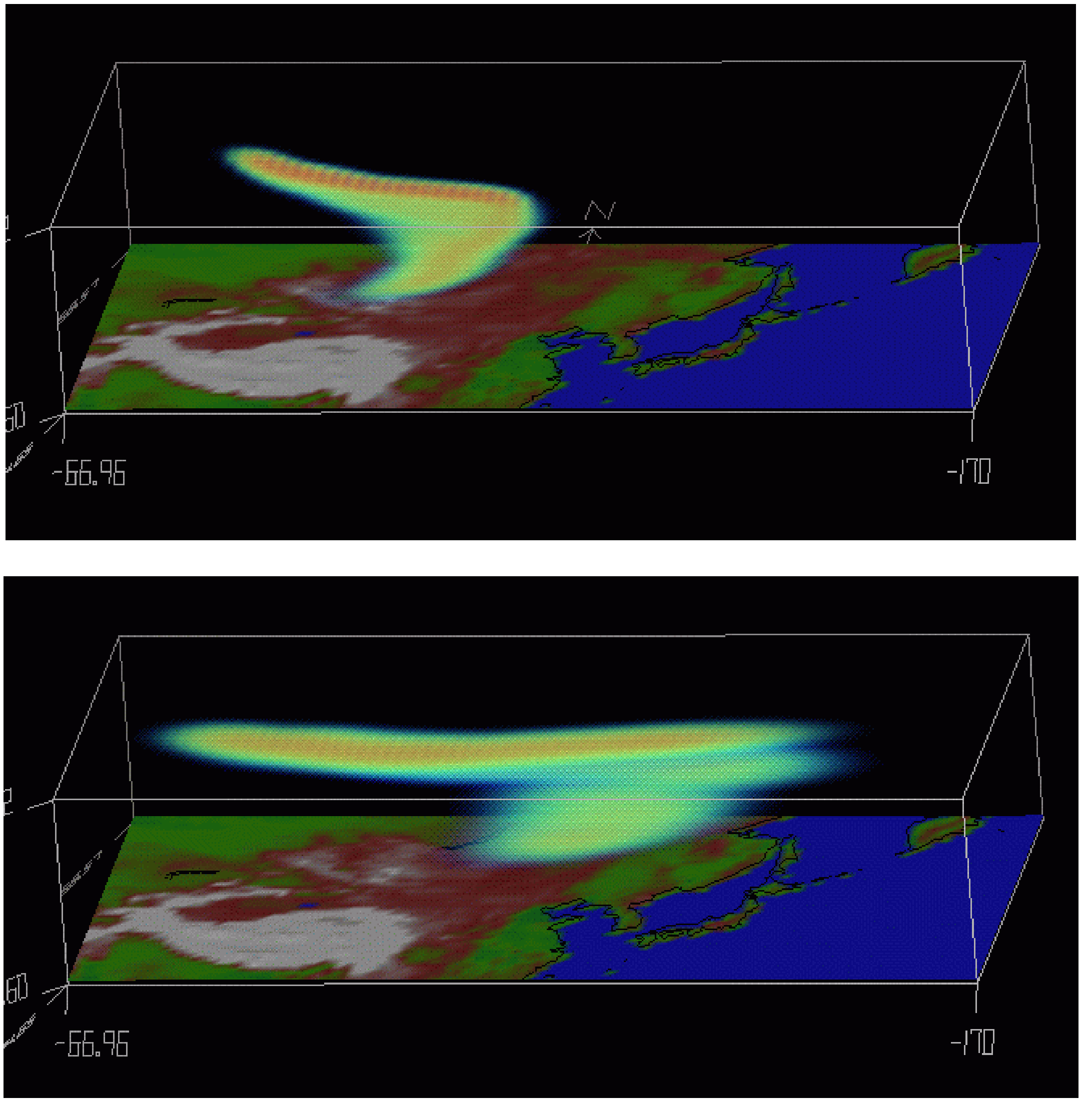

Figure 6. A 3-D visualization of the cloud after 12 hours (top) and 36 hours (bottom) of simulation time for the June 17, 1967/0300 UTC, 100m HOB case. The view is from the southeast looking northwest. The scale in the vertical is 0-25km, with the cloud anvil near 20 km.

simulated to have deposited to the east of the test range. The settling time of 20 micrometer particles, those that reach the stratosphere in this case, is about 10 days (Northrop, 1996). Thus I do not believe the stratospheric portion of the cloud would have yielded high levels of radiation to those living west of the site by several hundred kilometers or more.

17 June 1973, 0300 UTC: The HPAC plume and resulting surface dosage calculation are shown in Figure 7. Again 0300Z was assumed for detonation time and the location was assumed to be 41.7N, 88.383E. Figure 7 shows the 100m burst deposits radioactive material on the surface considerably farther downrange than the 1000m burst does, probably due to the additional surface materials lofted from a lower burst. Both the 100m and 1000m bursts loft a considerable amount of material into the atmosphere that remains suspended for many days and is transported much farther than the plots shown indicate.

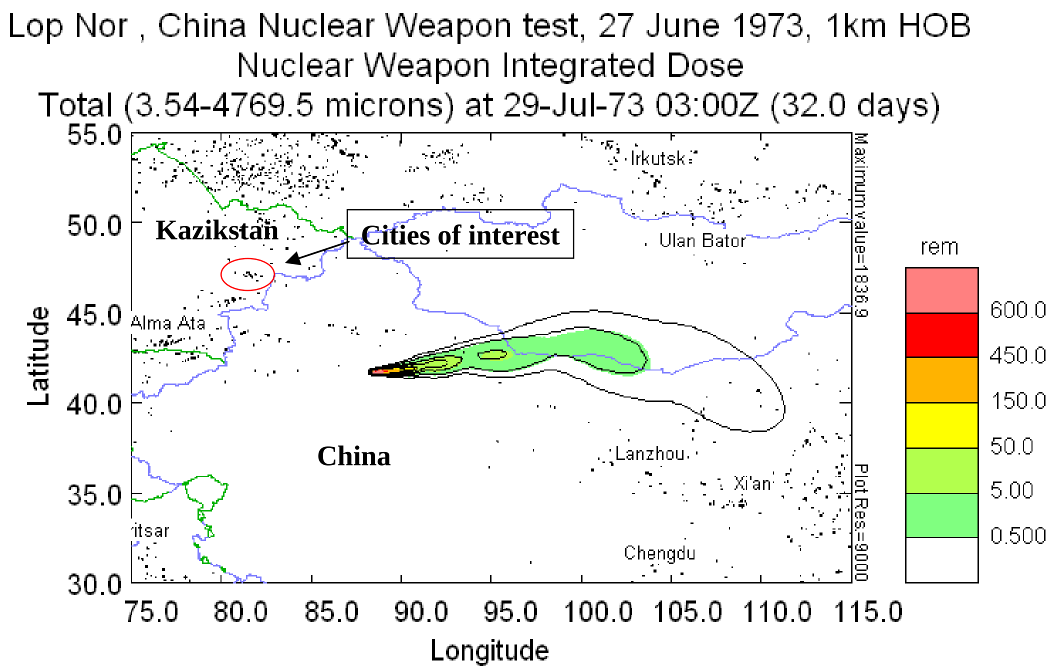

Figure 7. HPAC calculation with the same details as Figure 4, except for the date of detonation.

Further analysis of the plume shows there is some vertical shearing apparent that causes the portion lofted to stratospheric heights to stagnate. The upper levels of the simulated plume, though, do not travel as far to the west as for the 1967 case. Figure 8 shows an integration in the vertical dimension of the entire cloud. The figure shows 12- and 36-hour snapshots of the cloud as an integrated column. It is evident the entire cloud drifts to the east, with the upper levels stagnating somewhat. From this simulation it is apparent that there is little concern for inhabitants to the west.

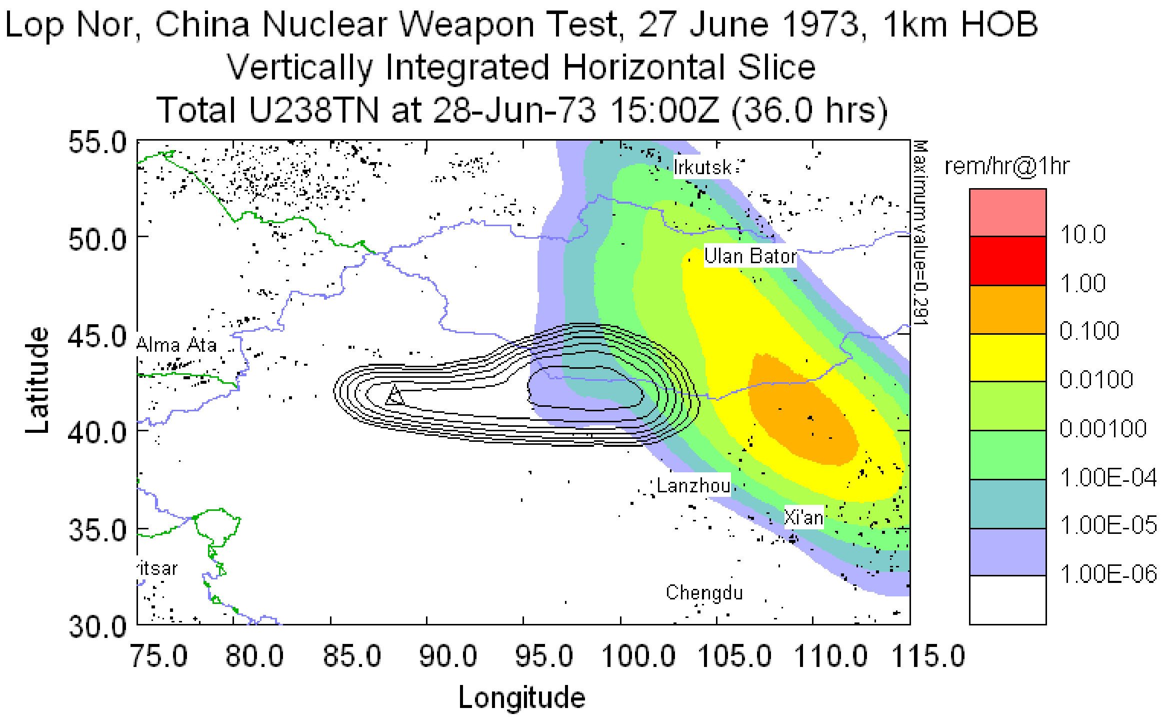

Figure 8. Vertically integrated slice of the cloud from the 1km HOB simulation. The figure shows the cloud at 12 hours (solid line contours) and 36 hours (colored contours) with the scale of each contour shown on the right. The triangle shows the assumed release location.

<u>Sources of Uncertainty.</u>

As with any transport and diffusion problem there are considerable uncertainties. The cases presented here involve additional uncertainty due to the age of the problem and the fact that we have no little meteorological data that generally accompany such tests. Sources of uncertainties and how they were dealt with include:

Uncertainty	Solution
Height of the burst	100m and 1km heights calculated
Distribution of materials lofted	Used legacy code, NewFall, which is based on empirical data. Any error affect radiation intensity, but not directional trends shown.
Meteorological conditions	Used best available data set (NCAR/NCEP Reanalysis) for input to a well validated model, RAMS to improve physical representation of complex terrain
Location and time of day (exact release data are classified)	Assumed 0300 UTC detonation at 41.7N, 88.383E. No transient weather systems appeared to be traversing the area on the test day. Time of day had minimal impact on cloud dispersal due to upper level wind consistency.

Conclusions

A fairly detailed reconstruction of the June 1967 and 1973 nuclear weapons above-ground tests was accomplished. The NCAR/NCEP Reanalysis data ingested into the RAMS weather model provided sound meteorological data to HPAC for downwind hazard calculations. Bursts at 100m and 1000m were simulated to cover the estimated range of possible burst heights. Simulations using the RAMS weather model and HPAC hazard prediction model showed the plume in both simulated heights of burst for both weapon test events to traverse to the east. A plume calculation using HPAC's climatological data for the month of June shows very similar plume in terms of direction.

Uncertainties of the entire problem notwithstanding, I believe it is unlikely that a significant amount of radioactive fallout could have resulted from the two nuclear tests studied here, at a distance of more than a couple hundred kilometers to the west of the Lop Nor, China test site. Although cloud shine was ignored for this study, I also believe it would have had minimal effects at locations west of Lop Nor.

A more detailed study, using classified information, could be performed to reduce some of the uncertainty associated with unclassified information. Some of the references for this information can be found in the References section below.

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